REPORT

Lynemouth Coastal Landfill

Site Characterisation and Interim Generic Quantitative Risk Assessment

Client: Northumberland County Council

Reference: PB9153-RHD-ZZ-XX-RP-Z-0001

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Executive Summary

Royal HaskoningDHV has been commissioned by Northumberland County Council to provide technical advice on the feasibility of options to manage the risks from eroding colliery spoil and waste materials from Lynemouth Bay, Northumberland. The objectives of this Interim Generic Quantitative Risk Assessment (GQRA), which supports the feasibility study, was to assess the data gathered as part of the 2019 ground investigation conducted by Dunelm on behalf of the Client, to update the conceptual site model which had been produced as part of the initial desk-top Preliminary Risk Assessment (PRA) and to provide information to support the consideration of options to manage the release of waste materials eroding from the cliff face.

The Lynemouth Coastal Landfill site has a long history of colliery spoil tipping, and its cessation, which has previously been discussed within the Lynemouth Coastal Landfill Contaminated Land Preliminary Risk Assessment (Royal HaskoningDHV, 2019). In addition to the colliery spoil tipping that has occurred within the Lynemouth Coastal Landfill site, both legal and illegal tipping of waste materials has occurred. The present issue at the site is the ongoing erosion of the previously tipped colliery spoil and other wastes by wave and tidal action throughout the bay and by fluvial flows along the river banks near the River Lyne. The ongoing erosion of the cliff face has left the waste materials exposed and, in some locations, it has become strewn across the foreshore and beach resulting in the potential for the waste materials to be washed into the sea and for public access to become restricted due to potentially unacceptable risks.

Two distinct types of Made Ground were observed across the site during the 2019 ground investigation, Made Ground associated with colliery spoil and Made Ground composed of unlicensed tipping waste (refuse). A hydrocarbon odour was recorded within the Made Ground of RH-BH05 at a depth of 7 – 9m below ground level (bgl). No additional visual/olfactory evidence of gross contamination was identified in the remaining exploratory hole locations both within the Made Ground and natural deposits.

Groundwater strikes were recorded within the Made Ground in four boreholes (RH-BH01, RH-BH02, RH-BH04 and RH-BH05) and one trial pit (TP07) at depths between 4.2m bgl (TP02) and 9m bgl (RH-BH02).

Whilst the assessment has identified a limited number of Potential Contaminants of Concern (PCOC) in the soils, groundwater and surface waters analysed, it is considered unlikely that they represent a significant possibility of significant harm. This assessment has been undertaken with respect with current site use (public open space). However, it should be noted that further groundwater and surface water samples are planned to be undertaken and therefore these findings should be deemed as ‘interim’, especially in relation to effects on controlled waters. This report will be updated when these further samples have been collected and analysed as the project progresses through future stages.

It should be noted that the risks from plastics and the refuse waste were not assessed as part of the human health risk assessment, however the risk remains to the landscape character of the area and to sensitive ecological receptors on and adjacent to the site from refuse waste in areas where erosion is actively taking place. Whilst quantifying this risk is difficult, the general principle is that release of plastics, rubbers and other refuse waste onto the beach and into the marine environment is likely to cause some degree of harm to both the landscape character of the area, and to any ecological receptors that come into contact with the waste, and so should ideally be avoided.

Glossary of Terms

Acronym	Definition	Common Occurrence/Explanation
CSM	Conceptual Site Model	The representation of the characteristics of a site that discusses the possible relationships between contaminants, pathways and receptors
CL:AIRE	Contaminated Land: Applications in Real Environments	Independent body promoting sustainable remediation of contaminated land and groundwater
CLEA	Contaminated Land Exposure Assessment	Technical guidance for the assessment of risks to human health from contaminants present within soils
EA	Environment Agency	The Regulator for the protection of the environment within England
EQS	Environmental Quality Standard	The concentration of a particular pollutant or group of pollutants in water which should not be exceeded in order to protect the environment
GAC	Generic Assessment Criteria	An assessment criterion based on a range of generic assumptions used for screening contaminant concentrations to facilitate an assessment of the potential risk to human health
GQRA	Generic Quantitative Risk Assessment	Screening of contaminant concentrations using GAC and consideration of the conceptual site model to determine if there are potential unacceptable risks
ICRCL	Interdepartmental Committee on the Redevelopment of Contaminated Land.	Technical guidance referenced within the CIRIA report.
LOD	Limit of Detection	The lowest concentration of a chemical that can be detected in a laboratory sample using current technology
MCERTS	Monitoring Certification Scheme	Standards set by the Environment Agency
NCC	Northumberland County Council	Client
PCB	Polychlorinated Biphenyls	Compounds used as dielectric and coolant fluids, for example in transformers, capacitors, and electric motors. The compounds are typically associated with oils
PAH	Polycyclic Aromatic Hydrocarbons	Hydrocarbon chemicals associated with coal and oils. Derived from fossil fuels and liberated by incomplete burning of fuels and biomass, and in barbecued food
PCOC	Potential Contaminants of Concern	Chemicals that could be hazardous to human health and controlled waters
PRA	Preliminary Risk Assessment	An early stage desk-based study to develop an initial conceptual site model

Acronym	Definition	Common Occurrence/Explanation
SVOC	Semi Volatile Organic Compounds	Chemicals with a higher boiling point than water, often related to fuels or plastics
TEM	Toluene Extractable Matter	Toluene extractable material and free sulphur in soils and water.
TPH	Total Petroleum Hydrocarbons	A mixture of chemicals found in crude oil
VOC	Volatile Organic Compounds	Chemicals that easily evaporate at room temperature
v/v%	Volume per Volume	Concentration of a specific hazardous gas.
w/w%	Weight per Weight	Weight of asbestos within a sample.
WQS	Water Quality Standard	Chemical standards for surface water and groundwater

1 Introduction

1.1 Background

Royal HaskoningDHV (RHDHV) was appointed by NCC to provide technical advice on the feasibility of options to manage the risks from eroding colliery spoil and waste materials from the cliffs of Lynemouth Bay, Northumberland.

The history of colliery spoil tipping, and its cessation, is discussed within the Lynemouth Coastal Landfill Contaminated Land Preliminary Risk Assessment (Royal HaskoningDHV, 2019). In addition to the colliery spoil tipping that has occurred within the Lynemouth Coastal Landfill site, both legal and illegal tipping of waste materials has occurred. The present issue at the site is the ongoing erosion of the previously tipped colliery spoil and other wastes by wave and tidal action throughout the bay and by fluvial flows along the river banks near the River Lyne. The ongoing erosion of the cliff face has left the waste materials exposed and, in some locations, it has become strewn across the foreshore and beach resulting in the potential for the waste materials to be washed into the sea and for public access to become restricted due to potentially unacceptable risks.

Following a desk-top review of available information, including an assessment of previous ground investigation data undertaken in 2006, an initial conceptual site model (CSM) was developed for the site and reported in a Preliminary Risk Assessment (PRA)[1]. The results of the desk-top review identified that there were unacceptable risks to sensitive receptors as a result of the current ground conditions present at the site. To further investigate this, the PRA recommended that an intrusive ground investigation be undertaken.

This report has been prepared by RHDHV for the sole benefit of Northumberland County Council and presents the finding of historical and contemporary assessments associated with the Lynemouth Coastal Landfill.

1.2 Key Objectives

The key objectives of this report are as follows:

- To present the findings of the 2019 ground investigation and subsequent assessment of the data;
- To present an updated conceptual site model identifying potential pollutant linkages and potential mitigation measures;
- To inform Northumberland County Council of any potentially unacceptable risks identified following an assessment of the data and update of the conceptual site model;
- To present recommendations regarding further studies and appropriate timings, if deemed necessary; and
- To provide information to support the consideration of options to manage the release of materials from the eroding cliff face.

[1] *RHDHV. 2019. Lynemouth Coastal Landfill - Contaminated Land Preliminary Risk Assessment*

1.3 Report Format

The remainder of the report comprises the following principal sections:

- Section 2 – Preliminary Risk Assessment: references the desktop review and provides clarification on issues that have emerged since drafting the original report
- Section 3 – Site Characterisation Studies: Presents the strategy and scope of works of various phases of ground investigation
- Section 4 – Proven Ground Conditions: Presents the findings of the intrusive investigation works
- Section 5 – Human Health Risk Assessment: Presents the methodology and findings of the human health generic assessment
- Section 6 – Interim Controlled Waters Risk Assessment: Presents the methodology and findings of an interim controlled waters generic assessment
- Section 7 – Ground Gas Monitoring and Assessment: Presents the methodology and findings of the ground gas monitoring
- Section 8 – Updated Conceptual Site Model
- Section 9 – Conclusions and Recommendations

2 Preliminary Risk Assessment

2.1 Initial Conceptual Site Model

A desk-based study[2] was previously undertaken by RHDHV which incorporated a tabulated Preliminary Conceptual Site Model (PCSM) for the Lynemouth Coastal Landfill site. The study incorporated a site walkover, procurement of a Landmark Envirocheck Report[3], review of existing reports[4] and a review of publicly available data via various online portals, for example the British Geological Survey GeoIndex.

The PCSM was limited to the identification and assessment of potential sources, potential receptors, and the anticipated pathways to those receptors identified through documentary research. The Preliminary CSM, which is included as Table 2-1 below, identified plausible pollutant linkages associated with the Lynemouth Coastal Landfill site. The key linkages identified were following the development of the PCSM were:

- Direct exposure from on-site contaminated sediment, soils or groundwater (through dermal contact, ingestion or inhalation) to current site users;
- Physical transport of contaminated soil and waste material to surface waters by coastal erosion;
- Leaching of any on-site contamination causing deterioration of shallow groundwater (which could be exacerbated via continued erosion) and migration to surface waters;
- Alteration of groundwater migration pathways due to erosion, ingress of coastal waters to the landfill sites and low-lying sources of contamination leading to the migration of off-site sources of aquifers beneath the site; and
- Migration of ground gases into temporary structures, excavations and migration off site via permeable soils and eroded coastline.

Table 2-1: Preliminary Conceptual Site Model and Qualitative Risk Assessment

Source	Pathway	Receptor	Qualitative Assessment
Potential contaminants of concern in Made Ground and groundwater as a result of the historical site use and off-site historical and current operations	Dermal contact, ingestion, & inhalation	Human Health (current and adjacent site users).	The documentary research has confirmed the site and their environs have been utilised by a range of industries, although primarily associated with coal mining, coal fired power generation and aluminium smelting. This past industrial may have resulted in ground contamination either as a result of poor operational practices or failures of environmental controls. Of particular concern is the historical deposition of colliery spoil across the site, as well as the deposition of other waste material which are evident in 'hot spot' areas. The full history of landfilling actives taking place in Lynemouth Bay is not reported within the Envirocheck Report or Environment Agency Records. Materials have been deposited on Lynemouth beach and its environs illegally and often unreported. Therefore, the full extent of anticipated landfilling materials and the nature of deposition in the site is uncertain. However, a review of aerial photograph and satellite images of the site and local anecdotal information indicates that the mouth of the River Lyne is anticipated to have the most significant amount of landfilled materials. This also corresponds with the areas of waste materials being reported onsite. The reported historic landfill site at Lynemouth (BGS historic landfill site – Lynemouth \ EA registered historic landfill site, EAHLD31794) is

[2] *RHDHV. 2019. Lynemouth Coastal Landfill - Contaminated Land Preliminary Risk Assessment*
[3] *Landmark Information Group. March 2019. Envirocheck Report Lynemouth. Order Ref: 198493383_1_1*
[4] *Faber Maunsell. 2006. Lynemouth Bay Reclamation Phase II, Geo-environmental Interpretive Report*

			present beyond the existing shoreline and the materials deposited here have likely been removed from site due to coastal erosion or during the reclamation activities previously undertaken. Extensive fly tipping and reworking of landfill materials has taken place across the site which corresponds to Local Authority registered landfill sites - Blindburn (PD 016) and several other recorded tips and landfills across the site which have been present since the 1970s. This area was then utilised for traveller housing. This was until the reclamation and encapsulation of contaminated materials in this area. Further historic landfilling and illegal dumping has been reported at the mouth of the River Lyne ("Victor's Tip"). However, the full extent and nature of the materials deposited in this area is unknown. The thickness and depth of capping materials or cover present within the site is unknown. Additionally, ongoing coastal erosion of the site is anticipated to be leading to the deterioration of any environmental controls which may have been present. Capping materials on the seaward edge are not intact and present an exposure risk and as such landfilled materials are eroding onto the beach front. Erosion of landfilled materials onto the beach frontage has led to waste materials and other potential sources of contamination becoming present within sediments and beach sands. The nature of these materials is unknown. However, visible evidence of potentially asbestos containing materials is evident and have been reported within BGS borehole records and were evident on the beach. The site is open to public access and is utilised for recreational activities, therefore the presence of eroding colliery spoil and other wastes represents a potential unacceptable risk to site users and off-site users if materials become mobilised in windy conditions i.e. asbestos fibres
	Dermal contact, ingestion, & inhalation	Ecological Systems	The Northumberland Coast Ramsar Site, Northumberland Shore and Creswell Dunes Local Nature Reserve are located at the north of the site. The Bay is also a designated Marine Conservation Zone and Special Protection Area. The potential sources of contamination outlined above also present a possible risk to ecological health. Erosion of landfilled materials onto the beach frontage has led to waste materials and other potential sources of contamination becoming present within sediments and beach sands. Waste materials eroded into surface waters and groundwaters could also present a possible pathway of exposure. The thickness and depth of capping materials or cover present within the site is unknown. Additionally, ongoing coastal erosion of the site is anticipated to be leading to the deterioration of any environmental controls which may have been present. Capping materials on the seaward edge are not intact and present an exposure risk to the dune ecosystem system. A number of designated sites are present on site and adjacent to the site.

			These sites are designated due to their biodiversity. The potential presence of potential contaminants of concern could also represent an unacceptable risk to these ecological receptors.
	Contaminant migration via leaching, ground-water transport	Surface waters (River Lyne, North Sea), Secondary A Aquifers. Designated sites, including conservation areas	As noted above there is the potential for contaminants to be present on site as result of historical activities. BGS borehole logs also indicate that landfilled material contains biodegradable material and household wastes. The exact depth of landfilled materials in relation to the superficial and bedrock aquifers is unknown. Landfill material containing hazardous chemicals could be placed in direct contact with shallow groundwaters. However, BGS borehole records indicates that clay is present below the central part of the site. This might restrict the migration and leaching of contaminates into groundwaters in this area. Where groundwaters have become contaminated there is the potential for migration of contaminates into the wider environment. There is the potential for contaminants to migrate in shallow groundwaters and enter surface waters. Existing studies have confirmed the presence of high permeability deposits in northern part of the site which are unlikely to provide protection to the Coal Measures. This means there is the potential for migration of contaminants identified with the sources to migrate to the aquifer below and be discharged to surface waters. The historical ground investigation also suggests that contamination isn't confined to the Made Ground and may have been deposited within the beach deposits, and waste materials maybe directly in contact with Secondary A Aquifer below. However, the ground conditions of the site have not been previously assessed in detail and records of the nature and condition of the materials deposited are uncertain. Based on the information currently available we consider that feasible pollutant linkages to surface and groundwaters may be present in the site.
	Direct Entry	Surface waters (River Lyne, North Sea), Secondary A Aquifers. Designated sites, including conservation areas	Erosion of landfilled materials onto the beach frontage has led to waste materials and other potential sources of contamination becoming present within sediments and beach sands. The nature of these materials is unknown. However, visible evidence of potentially asbestos containing materials is evident. Based on the information currently available feasible pollutant linkages may present at the site.
Ground gases	Gas generation and migration	Human health Site infrastructure	Due to the industrial and commercial nature of the area (coal mining, landfilling), and the nature of the underlying strata, ground gas may be present at the site. BGS borehole logs indicate that landfilled material contains biodegradable material and household wastes. The site is located within a high-risk development area and mining works have occurred within the sites and the surrounding environs. As such mine gas sources may have potential migration pathways to the surface.

			Gas generated by the degradation of fill materials presents the following risks: • human health (toxic effects); • asphyxiation risks through accumulation of gases in temporary structures; and • explosion risks to site occupants and buildings. In the absence of buildings and confined spaces on site the risks to human health/structures is reduced. However, temporary structures, excavations, and migration off-site could present plausible exposure pathways. Based on the information currently available feasible pollutant linkages may present at the site.

2.2 Uncertainties in the Preliminary Conceptual Site Model

It is considered that there were uncertainties associated with the PCSM, primarily associated with determining potential sources, and the respective pathways as summarised below:

- The presence, magnitude and extent of potential contaminants of concern (PCOC) which need to be established to determine potentially unacceptable risks to human health, controlled waters and property.
- Characterisation of the geological and hydrogeological regime at the site which needs to be established in order to determine the potential for contaminant migration.

Further investigation and assessment were therefore considered necessary.

2.3 Ecologically Sensitive Receptors

A review of the Department for Environment Food and Rural Affairs (DEFRA) and the Natural England database of designated sites[5] shows that the wider area and Lynemouth Bay is adjacent to two Sites of Special Scientific Interest (SSSI), a Ramsar Site, two (overlapping) Marine Conservation Zones (MCZs), a Special Protection Area (SPA) and a Local Nature Reserve. The details are provided below in Table 2-2.

Table 2-2 Designated Sites

Distance	Site Name	Designation	Interest	Reason
On site (northern point)	Northumberland Shore	SSSI	Biological	Providing important wintering grounds for shore birds.
Adjacent east	Cresswell And Newbiggin Shores	SSSI	Geological	Important for both Westphalian and Quaternary studies.
Adjacent north	Northumbria Coast	Ramsar Site	-	-
On site	Cresswell Dunes	Local Nature Reserve	-	-
Adjacent East	Croquets to St Mary's	Marine Conservation Zone	-	Designated features comprise numerous intertidal and subtidal habitats.
Adjacent East	Berwick to St Mary's	Marine Conservation Zone	-	Protected features is the common eider.
Adjacent East	Northumberland Marine	Special Protection Area	-	Protects numerous species of birds.
Approximately 750m	Northumbria Coast	Special Protection Area	-	Protects numerous species of birds.

[5] https://designatedsites.naturalengland.org.uk/SiteSearch.aspx

3 Site Characterisation Studies

This section of the report presents a summary of the previous and present ground characterisation investigations undertaken at the Lynemouth Coastal Landfill site. The actual ground conditions encountered are presented in Section 4 and the data assessments on human health and controlled waters (interim assessment) are presented in Sections 5, 6, respectively.

3.1 Lynemouth Bay[4] 2006

3.1.1 Background

A site investigation was undertaken in 2005/06 to inform the Lynemouth Bay Regeneration Scheme that was undertaken by Northumberland County Council. The aim of the scheme was to improve the coastline in this area to develop an ecological corridor. The ecological corridor aimed to link up the special conservation zones at the north and southern ends of Lynemouth Bay. The geo-environmental investigation was to quantitatively assess risks to human health and the environment.

3.1.2 Ground Investigation Objectives

The main objectives of the investigation were to:

- To determine the spatial extent and depth of the existing colliery spoil and calculate the approximate volume for treatment (in the northern part of the site – referred to as Area C in the RHDHV PRA[2] (2019)) as part of the 'regeneration' work;
- To determine the ground conditions in the sand dunes and the area intended for the deposition of stabilised spoil following remediation;
- Install groundwater monitoring wells through the sand dunes to determine the presence of perched groundwater horizons and obtain groundwater samples;
- Obtain soil samples of soil for geotechnical testing;
- Obtain samples of soil and water samples for chemical analysis to obtain parameters needed to quantify potential risks to human health; and
- Collection of groundwater samples from boreholes and surface water samples from pools in the spoil to assess the temporal variability of water quality on the beach.

3.1.3 Investigation and Sampling Strategy

A total of four cable percussion boreholes to depths of approximately 10m below ground level (m bgl) were drilled and 12 trial pits were excavated from the surface beach materials to depths ranging from 2.9 and 4.1m bgl. The investigation reported that an estimated 170,000m^3 of spoil has been placed in this area of the site.

Soil samples were obtained both from Made Ground and natural strata.

Combined ground gas and groundwater monitoring wells were installed in two boreholes and a groundwater monitoring well was installed in one borehole. The response zones were located within the Made Ground and natural deposits. Monitoring visits were conducted between July and September 2005, three monitoring rounds of groundwater were conducted and a single round of monitoring for ground gas.

3.1.4 Laboratory Analysis

Laboratory analysis incorporated a range of PCOC (arsenic, cadmium, chromium, lead, mercury, nickel and zinc) that could be associated with the environs. Chemical testing for soils included metals, sulphurous compounds, pH, chloride, TEM and PAH. Leachate testing was undertaken on selected samples, the number of which is not provided in the information received, to assess concentrations of metals, sulphurous compounds, chloride, COD and TOC.

Laboratory analysis of water samples included major anions and cations, metals, pH, TOC, COD, total suspended solids and sulphide.

3.2 Lynemouth Coastal Landfill[6] 2019

The Lynemouth Coastal Landfill 2019 ground investigation was designed by RHDHV and carried out by Dunelm Geotechnical and Environmental (Dunelm). Two site supervision visits were conducted during the works with regular phone calls between RHDHV and Dunelm to discuss installation details and any queries that arose during the works. Following a review of the available information the site was designated as a red site, as such appropriate working practices were implemented in order to protect those working on site.

Figure 1: Sampling Location Plan

[6] *Dunelm Geotechnical and Environmental. 2019. Factual Report of Lynemouth Coastal Landfill Ground Investigation.*

3.2.1 Ground Investigation Objectives

The main objectives of the investigation were:

- To determine and confirm the ground conditions previously identified within the site;
- To collect soil samples, both Made Ground and natural deposits, for chemical laboratory analysis;
- To collect surface water samples from the River Lyne for chemical laboratory analysis;
- To collect groundwater samples from borehole for chemical laboratory analysis; and
- To undertake three rounds of ground gas and groundwater monitoring within the boreholes.

3.2.2 Investigation and Sampling Strategy

A total of ten cable percussive boreholes to depths of between 8m bgl and 11.5m bgl were drilled, 23 trial pits were excavated to depths ranging from 3.1m bgl to 5.3m bgl. In addition to these, 25 hand dug pits were excavated to depths ranging from 0.6m bgl to 1m bgl.

Ten groundwater monitoring wells were installed in each of the boreholes during the ground investigation works with the response zones generally located within the Made Ground deposits. Within RH-BH04, the response zone targeted the boundary between the Made Ground and natural deposits. RH-BH03, RH-BH09 and RH-BH10 had response zones located within the natural deposits.

For cable percussive boreholes and trial pits, small disturbed samples were scheduled to be sampled for environmental testing every 0.5m within the top metre below ground level, then one every 1m to a maximum depth of 2m below the Made Ground. Hand dug samples were scheduled to be collected from the surface and 0.5m bgl. Additional samples were scheduled to be taken at appropriate changes in soil type and/or where visual or olfactory evidence of contamination was encountered.

Groundwater samples were collected from five monitoring wells on the 18th October 2019. Prior to the sample been collected, the wells were purged until three well volumes had been removed or redox potential, electrical conductivity, pH and temperature measurements had stabilised.

Five surface water samples were collected along the River Lyne (see drawing No. D9709/02 provided by Dunelm Geotechnical – Appendix B), samples were collected from the near surface of the river.

Note: The Environment Agency recommends that a minimum of two further rounds of groundwater and surface water sampling be undertaken as the project progresses through its next stages, and these data be analysed and the results interpreted to enable an update of the 'interim' controlled waters risk assessment that is presented in Section 6.

3.2.3 Laboratory Analysis

Laboratory analysis incorporated a range of PCOC that could be associated with the environs. Chemical testing for soils included metals, total petroleum hydrocarbons (TPH), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAH), asbestos, volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs).

Laboratory analysis for PCOC groundwater and surface water samples included metals, pH, TPH, PAH, VOCs and SVOCs.

3.2.4 Results

Laboratory analysis undertaken during the ground investigation incorporated a range of PCOC that could be associated with the environs. The results for chemical testing for soils are discussed within Section 5 for human health and Section 6 for controlled waters (interim assessment).

4 Proven Ground Conditions

4.1 Historical BGS Boreholes

Historical borehole records were accessed via the British Geological Survey as part of the RHDHV PRA (2019). A summary of the ground conditions is presented below in Table 4-1.

Table 4-1: Summary of Historical Borehole Logs

Geology	Depth range (m bgl)	Description
Made Ground	0 – 8.4	Sand and silt capped waste deposits containing materials deposited from several waste streams. Materials previously identified include asbestos, timbers, metals, glass, ash, rubber, cables and fly tipped household goods.
Blown Sand/Marine Deposits/Till	From 3 to base of excavations	Orange brown sand and gravel with some cobbles and occasional bounders of sandstone and mudstone. Compact brown sand and fine to coarse gravel.
Pennine Middle Coal Measures Formation (possible)	2.6 to 2.7 (base of excavation)	Light brown medium to coarse grained sandstone.
	5.5 to 6 (base of excavation) 7.2 to 7.57 (base of excavation) 7.1 to 7.5 (base of excavation)	Weathered light greenish brown medium grained sandstone.

4.2 Lynemouth Bay Investigation - 2006

The ground investigation comprised four boreholes (to depths of 10m bgl) and twelve trial pits (to depths ranging from 2.9m bgl and 4.1m bgl). A summary of the ground conditions encountered is presented in Table 4-2 below.

Table 4-2: Summary of Ground Conditions Encountered During the 2006 Ground Investigation

Geology	Depth range (m bgl)	Description
Made Ground	0 – 7.6	Colliery waste comprising grey clays, sands, gravels and fused ash. Gravel comprised mudstone, siltstone, sandstone and coal. Plastic/rubber sheeting was recorded at 0.9m bgl within one of the trial pits.
Blown Sand	0 - 3	Sand
Natural Deposits	To 10.3	Firm to stiff brown, slightly sandy, slightly gravelly clay.
Bedrock	8.4 to base of excavation	Very weak, weathered mudstone.

Groundwater was encountered within the colliery spoil within one location (TP12) and at multiple locations within the Blown Sand deposits.

4.3 Lynemouth Coastal Landfill Investigation – 2019

The ground investigation comprised ten boreholes (to depths ranging from 8 to 11.5m bgl), 23 trial pits (to depths ranging from 3.1 to 5.3m bgl) and 26 hand pits (to depths ranging from 0.6 to 1m bgl). A factual summary of ground conditions recorded is presented in Table 4-3, Table 4-4 and Table 4-5. This information will be summarised further to refine a conceptual understanding of the ground conditions at the site as part of the updated GQRA as the project progresses to future stages.

Table 4-3: Summary of Borehole Logs

Borehole ID	Geology	Depth range (m bgl)	Description
RH-BH01	Made Ground	0 – 10*	Dark grey sandy, gravelly clay. Sand is fine to coarse with much ash. Gravel is fine to coarse, angular to subrounded sandstone, coal, clinker and brick. Cobbles and/or boulders of brick noted as are frequent timber and glass fragments.
RH-BH02	Made Ground	0 – 10*	Dark grey slightly sandy, gravelly clay. Sand is fine to coarse with much ash. Gravel is fine to coarse, angular to subrounded sandstone, coal, clinker and brick. Rare timber and glass fragments noted throughout.
RH-BH03	Made Ground	0 – 3.5	Yellowish brown slightly sandy gravel. Gravel is fine to coarse, subangular to subrounded of sandstone and limestone (0 -0.6m). Dark grey slightly sandy, gravelly clay. Sand is fine to coarse with much ash. Gravel is fine to coarse, subangular to subrounded of sandstone, coal, clinker and brick. Frequent timber and glass fragments noted. Cobbles and/or boulders of sandstone and brick noted (0.6 -3.5m).
	Natural deposits	3.5 -8*	Brown slightly gravelly sand/sand and gravel/slightly sandy slightly gravelly clay. Sand is fine to coarse. Gravel is angular to subrounded, fine to coarse of sandstone and coal. Cobbles and/or boulder of sandstone noted (7 - 8m*).
RH-BH04	Made Ground	0 - 9	Brown slightly gravelly sand/grey slightly sandy gravelly clay. Gravel is subangular to subrounded, fine to coarse of sandstone, clinker, brick and coal. Cobbles and/or boulders of brick and sandstone noted. Black gravelly sand. Sand is fine to coarse, predominantly ash, gravel is fine coal (8 -9m).
	Natural deposits	9 -10*	Brown sandy gravel. Gravel is rounded to subrounded, fine to coarse of sandstone and coal.
RH-BH05	Made Ground	0 – 9	Brown slightly gravelly sand/dark grey slightly sandy gravelly clay/dark brown slightly gravelly sandy clay. Gravel is subangular to subrounded, fine to coarse of sandstone, coal, glass, timber, brick, concrete, clinker and coal. Frequent fabric, glass and timber fragments notes (1 – 2m). Hydrocarbon odour between 7 – 9m. Sand is fine to coarse predominantly ash (8 – 9m).
	Natural deposits	9 – 11.5*	Dark brown sand and gravel. Gravel is subangular to subrounded, fine to coarse of sandstone, coal and mudstone.
RH-BH06	Made Ground	0 – 8	Dark grey slightly sandy, gravelly clay. Sand is fine to coarse with much ash. Gravel is fine to coarse, angular to subrounded of sandstone, coal, clinker and brick. Rare timber and glass fragments noted (0 – 3m).
	Natural deposits	8 -8.4*	Orangey brown gravelly sand. Gravel is fine to coarse, angular to subrounded of sandstone (possible sandstone rockhead).
RH-BH07	Made Ground	0 – 6	Dark brown to dark grey slightly gravelly, sandy topsoil/slightly gravelly sand. Gravel is subangular to subrounded, fine to coarse of sandstone, coal, clinker and brick.
	Natural deposits	6 -7	Brown sand and gravel. Gravel is subangular to subrounded, fine to coarse sandstone and coal.

Borehole ID	Geology	Depth range (m bgl)	Description
	Natural deposits	7 – 8.5*	Stiff brown slightly sandy, slightly gravelly clay. Gravel is subangular to subrounded, fine to coarse of sandstone and coal.
RH-BH08	Made Ground	0 – 10*	Grey to dark brown sandy, gravelly clay/ slightly gravelly, slightly clayey sand. Gravel is subangular to subrounded, fine to coarse of sandstone, coal, clinker and brick. Sand is fine to coarse, predominantly ash (6 – 10m*).
RH-BH09	Made Ground	0 - 7	Brown slightly gravelly, sandy topsoil. Gravel is subangular to subrounded, fine to coarse of sandstone and coal (0 – 0.1m) Brown slightly gravelly sand/dark grey slightly sandy, slightly gravelly clay/dark brown slightly clayey sand. Gravel is subangular to subrounded, fine to coarse of sandstone, clinker, brick, concrete and coal. Occasional timber and rags noted (1 – 5m). Sand is fine to coarse predominantly of ash. Cobbles and/or boulders of concrete and brick noted (5 – 7m).
	Natural deposits	7 – 10	Brown gravelly sand. Gravel is subangular to subrounded, fine to coarse of sandstone and coal.
	Natural deposits	10 – 11.3	Stiff greyish brown slightly sandy slightly gravelly clay, gravel is subangular to subrounded, fine to coarse of sandstone and coal
	Natural deposits	11.3 – 11.5*	Brown gravelly sand. Gravel is angular to coarse of sandstone (possible rockhead).
RH-BH10	Made Ground	1 - 6	Brown slightly gravelly sand/dark grey slightly sandy, gravelly clay. Gravel is subangular to subrounded, fine to coarse of sandstone, clinker, brick and coal. Frequent textile and timber fragments noted (0.5 – 2m).
	Natural deposits	6 - 7	Orangish grey slightly gravelly sand. Gravel is subangular to subrounded, fine to coarse sandstone and coal.
	Natural deposits	7 – 11.5*	Stiff greyish brown slightly sandy, slightly gravelly clay. Gravel is subangular to subrounded, fine to coarse of sandstone and coal.

*Base of borehole

Table 4-4: Summary of Trial Pits

Trial Pit ID	Geology	Depth range (m bgl)	Description
TP1	Made Ground	0 – 4.5*	Soft to firm very dark brown, slightly clayey, gravelly sand/slightly sandy, gravelly clay. Gravel is angular to subangular, fine to coarse of coal, sandstone, mudstone and clinker. Occasional metal wire noted. Metal drum recorded at 1m, metal container filled with crystalline substance at 1.5m.
TP2	Made Ground	0 – 4.7*	Brown to dark brown, slightly clayey, slightly silty, gravelly sand. Gravel is angular to subangular, fine to coarse of sandstone, mudstone, limestone, clinker and coal. Cobbles of subangular mudstone (2.2 – 3.4m). Occasional glass and timber fragments noted between 3.4 – 4.2m.
TP3	Made Ground	0 – 5*	Dark brown, slightly clayey, gravelly, sand with medium cobble content. Gravel is angular to subrounded, fine to coarse of sandstone, mudstone,

Trial Pit ID	Geology	Depth range (m bgl)	Description
			coal, clinker and brick. Occasional glass and plastics noted. Cobbles are angular to subangular of sandstone and mudstone.
TP4	Made Ground	0 – 4.5*	Brown, slightly clayey, gravelly sand. Gravel is angular to subangular, fine to coarse of coal, mudstone, sandstone and clinker. Frequent fragments noted. Firm at 2.9 – 4.5*.
TP5	Made Ground	0 – 5.15*	Brown, slightly clayey, gravelly sand with medium cobble and boulder content/slightly silty, silty, slightly gravelly sand. Gravel is angular to subrounded, fine to coarse of mudstone, sandstone, coal, clinker and brick. Cobbles and/or boulders are subangular to angular of concrete, coal, brick and mudstone up to 700mm. Rare metal fragments noted (0 – 0.8m). Frequent timber fragments noted (2.6 – 5.15m*)
TP6	Made Ground	0 – 3.9*	Brown, slightly clayey, slightly silty, very gravelly sand/dark brown, slightly silty, sandy, gravelly clay. Gravel is angular to subrounded, fine to coarse of brick, sandstone, clinker, coal and mudstone. Frequent plastic, timber, clay pipe and general refuse noted (1.1 – 2.9m)
TP7	Made Ground	0 – 4.3*	Brown, slightly silty, gravelly sand/dark brown, slightly sandy, gravelly clay with medium cobble content. Gravel is angular to subrounded, fine to coarse of brick, mudstone, sandstone. clinker and coal. Cobbles are subangular of mudstone, brick and sandstone.
TP8	Made Ground	0 – 4.7*	Brown, slightly silty, gravelly sand/dark brown slightly sandy, gravelly clay with low cobble content. Gravel is angular to subangular, fine to coarse of sandstone, mudstone, brick and coal. Cobble are angular to subangular of sandstone and mudstone. Frequent metal wire and glass fragments noted (0.75 – 4.3m).
TP11	Made Ground	0 – 3.5*	Brown sandy, slightly gravelly topsoil. Gravel is subangular to subrounded, fine to coarse of sandstone. Rootles noted (0 – 0.4m). Dark grey slightly sandy, gravelly clay/light greyish brown sand/orange greyish brown slightly gravelly sand. Gravel is angular to subrounded, fine to coarse of sandstone, coal, clinker and brick. Frequent cloth, rubber, metal and plastic fragments noted (0.4 – 1m).
TP12	Made Ground	0 – 5*	Brown, slightly gravelly sand/dark brown, slightly sandy, gravelly clay with low cobble content. Gravel is angular to rounded, fine to coarse of sandstone, mudstone, coal and concrete. Occasional timber fragments noted (1 – 3.1m).
TP13	Made Ground	0 - 4.5*	Brown, slightly gravelly sand/dark brown to black, slightly sandy, gravelly clay with low cobble content. Gravel is angular to rounded, fine to coarse of sandstone, clinker, coal, bricks and mudstone. Cobbles are angular of sandstone. Sand is predominantly ash (>0.35m). timber and plastic refuse encountered at 3m.
TP14	Made Ground	0 – 4.1*	Brown sandy, slightly gravelly topsoil. Gravel is subangular to subrounded, fine to coarse of sandstone. Rootlets noted (0 – 0.5m). Dark grey sandy gravelly clay. Gravel is angular to subrounded, fine to coarse of sandstone, coal and clinker. Frequent cloth, rubber, metal and plastic fragments noted 90.5 – 4.1m*).

Trial Pit ID	Geology	Depth range (m bgl)	Description
TP15	Made Ground	0 – 5.2*	Brown, slightly clayey, slightly gravelly sand/slightly sandy, gravelly clay. Gravel is angular to subrounded, fine to coarse of mudstone, coal, clinker, brick, concrete and sandstone. Redundant gas pipe encountered at 0.2m. Frequent glass fragments noted (0.65 – 5.2m*). Concrete boulder recovered at 2.6m. Frequent timber fragments (3.2 – 5.2m*). Sand is predominantly ash 3.3 – 5.2m*
TP16	Made Ground	0 – 5.3*	Brown, slightly gravelly sand/dark brown, clayey, sandy gravel with a low cobble content. Gravel is angular to rounded, fine to coarse of sandstone, mudstone, clinker, coal and brick. Cobbles are angular to rounded of brick, mudstone and sandstone. General refuse noted (0.9 – 2.1m). Frequent glass fragments noted (0.9 – 3.9m). Sand is predominantly ash (3.9 – 5.3m*).
TP17	Made Ground	0 – 4.7*	Brown, slightly silty, gravelly sand. Gravel is fine to coarse, angular to subrounded of mudstone, sandstone, clinker and brick. Frequent glass fragments noted throughout. General refuse noted (0.6 – 3.6m).
TP18	Made Ground	0 – 3.1*	Light brown, slightly gravelly sand/dark brown, slightly sandy, gravelly clay. Gravel is angular to subrounded, fine to coarse of sandstone, mudstone and brick. Frequent timber, wire, plastic fragments and metal wire noted (0.65 – 3.1m*).
TP19	Made Ground	0 – 4.1*	Brown, slightly silty, very sandy, slightly gravelly topsoil with low cobble content. Gravel is rounded to subrounded, fine to coarse of sandstone. Cobbles are subangular of sandstone (0 – 0.2m). Dark brown, slightly silty, gravelly sand. Gravel is angular to subrounded, fine to coarse of sandstone, mudstone, clinker and coal. Cobbles are angular to subangular of brick, sandstone and mudstone. Frequent metal, rubber, pottery and glass fragments (0.2 – 1.5m).
TP20	Made Ground	0 – 5*	Brown, gravelly sand/slightly sandy gravelly clay. Gravel is angular to subrounded of sandstone, mudstone, brick and clinker. Frequent glass, timber, ceramic, metal, wire and pipework noted (0.7 – 5m*). Reinforced concrete boulder at 4m.
TP21	Made Ground	0 – 4*	Brown, slightly gravelly sand/slightly sandy, slightly gravelly sand with low cobble content/slightly clayey, very sandy gravel. Gravel is angular to

Trial Pit ID	Geology	Depth range (m bgl)	Description
			subrounded, fine to coarse of sandstone, mudstone, clinker and coal. Cobbles are subangular of mudstone.
TP22	Made Ground	0 – 4*	Brown sandy slightly gravelly topsoil (0 – 0.05). Brown sand/brown slightly silty, slightly gravelly sand with low cobble content/dark brown slightly sandy, very clayey gravel. Gravel is angular to subrounded, fine to coarse of sandstone, mudstone and coal. Cobbles are subangular of mudstone.
TP23	Made Ground	0 – 3.2*	Dark brown, slightly clayey, slightly gravelly sand. Sand is fine to coarse predominately of ash (0 – 1.2m). gravel is angular to subrounded, fine to coarse of mudstone, brick, coal and sandstone. Frequent timber fragments noted (1.2 – 3.2m*).
TP24	Made Ground	0 – 3.6*	Brown slightly gravelly sand/dark grey sandy gravelly clay. Gravel is angular to subrounded, fine to medium of sandstone, clinker, brick and coal. Frequent timber fragments noted (2.4 – 3.6m*).
TP25	Made Ground	0 – 3.6*	Brown slightly gravelly sand/dark grey sandy gravelly clay. Gravel is angular to subrounded, fine to medium of sandstone, clinker, brick and coal. Frequent timber fragments noted (1 – 3.6m*).

*Base of trial pit

Table 4-5:Summary of Hand Dug Pits

Hand Dug Pit ID	Geology	Depth range (m bgl)	Description
RH-HDP-01	Made Ground	0 – 1*	Brown sandy topsoil (0 – 0.02m). Brown, slightly silty, slightly gravelly sand. Gravel is angular to subrounded, fine to coarse of mudstone, clinker, coal and sandstone.
RH-HDP-02	Made Ground	0 – 1*	Brown, slightly silty, gravelly sand with a low cobble content. Gravel is angular to subrounded, fine to coarse of sandstone, mudstone, coal and clinker. Cobbles are angular of mudstone.
RH-HDP-03	Made Ground	0 – 1*	Brown, slightly gravelly, sandy topsoil. Gravel is rounded to subrounded, fine to coarse of sandstone (0 – 0.08m). Brown, slightly silty, very gravelly sand. Gravel is angular to subangular, fine to coarse of mudstone, coal, clinker and sandstone (0.08 – 1m*).
RH-HDP-04	Made Ground	0 – 1*	Brown sandy topsoil (0 – 0.05m). Slightly silty, gravelly sand. Gravel is angular to subrounded, fine to coarse of mudstone, sandstone, clinker and coal (0.05 – 1m*).
RH-HDP-05	Made Ground	0 – 1*	Brown, sandy topsoil (0 – 0.15m). Brown, slightly gravelly sand. Gravel is rounded to subrounded, fine to coarse of sandstone (0.15 – 1m*).
RH-HDP-06	Made Ground	0 – 1*	Brown, slightly gravelly sand with a low cobble content. Gravel is angular to subrounded, fine to coarse of sandstone and mudstone. Cobbles are subangular of concrete.

Hand Dug Pit ID	Geology	Depth range (m bgl)	Description
RH-HDP-07	Made Ground	0 – 1*	Brown, slightly clayey, slightly gravelly sand. Gravel is angular to subrounded, fine to coarse of mudstone, clinker and sandstone.
RH-HDP-08	Made Ground	0 – 1*	Slightly clayey, slightly gravelly sand. Gravel is angular to subrounded, fine to coarse of mudstone, clinker and sandstone.
RH-HDP-08A	Made Ground	0 – 1*	Slightly sandy, gravelly clay/slightly clayey, sandy gravel with a low cobble content. Gravel is angular to subrounded, fine to coarse of mudstone, clinker and sandstone. Cobbles are angular of mudstone.
RH-HDP-09	Made Ground	0 – 0.6*	Brown, slightly gravelly sand with a low cobble content. Gravel is rounded to subrounded, fine to coarse of mudstone, coal, clinker and sandstone. Cobbles are angular of mudstone.
RH-HDP-10	Made Ground	0 – 1*	Brown, slightly gravelly sand. Gravel is rounded to subrounded, fine to coarse of sandstone, mudstone and coal.
RH-HDP-11	Made Ground	0 – 1*	Brown, slightly gravelly sand/very dark brown, slightly clayey, gravelly sand. Gravel is angular to subrounded of mudstone. Gravel is angular to subrounded, fine to coarse of sandstone and mudstone.
RH-HDP-12	Made Ground	0 – 0.7	Light brown, slightly gravelly sand with a low cobble content. Gravel is rounded to subrounded, fine to coarse of coal, clinker, mudstone and sandstone. Cobbles are angular of sandstone and mudstone.
	Natural deposits	0.7 – 1*	Brown, slightly gravelly sand. Gravel is fine to medium of sandstone and mudstone.
RH-HDP-13	Made Ground	0 – 1*	Brown, gravelly sand. Gravel is rounded to subrounded, fine to coarse of coal, clinker, mudstone and sandstone.
RH-HDP-14	Made Ground	0 – 1*	Brown to grey, slightly gravelly sand. Gravel is subangular to subrounded, fine to coarse of sandstone, mudstone and coal.
RH-HDP-15	Made Ground	0 – 1*	Brown to grey, slightly gravelly sand. Gravel is subangular to subrounded, fine to coarse of sandstone, mudstone and coal.
RH-HDP-16	Made Ground	0 – 1*	Brown to grey, slightly gravelly sand. Gravel is subangular to subrounded, fine to coarse of sandstone, mudstone and coal.
RH-HDP-17	Made Ground	0 – 1*	Greyish brown slightly gravelly sand/dark grey slightly sandy, slightly gravelly clay. Gravel is subangular to subrounded, fine to coarse of sandstone, mudstone and coal.
RH-HDP-18	Made Ground	0 – 1*	Greyish brown slightly gravelly sand/dark grey slightly sandy, slightly gravelly clay. Gravel is subangular to subrounded, fine to coarse of sandstone, mudstone and coal.
RH-HDP-19	Made Ground	0 – 1*	Brown to grey, slightly gravelly sand. Gravel is subangular to subrounded, fine to coarse of sandstone, mudstone and coal.
RH-HDP-20	Made Ground	0 – 1*	Brown to grey, slightly gravelly sand. Gravel is subangular to subrounded, fine to coarse of sandstone, mudstone and coal.
RH-HDP-21	Made Ground	0 – 1*	Brown to grey, slightly gravelly sand. Gravel is subangular to subrounded, fine to coarse of sandstone, mudstone and coal.
RH-HDP-22	Made Ground	0 – 1*	Slightly gravelly sand/soft, light grey, slightly gravelly sandy clay. Gravel is angular to subrounded, fine to coarse of mudstone, clinker, sandstone and brick.
RH-HDP-23	Made Ground	0 – 1*	Dark brown gravelly, slightly clayey sand with a medium cobble content/dark grey slightly sandy, gravelly clay. Gravel is subangular to

Hand Dug Pit ID	Geology	Depth range (m bgl)	Description
			subrounded, fine to coarse of sandstone, clinker, coal and brick. Cobbles are subrounded of sandstone, mudstone and brick.
RH-HDP-24	Made Ground	0 – 1*	Dark brown gravelly, slightly clayey sand with a medium cobble content/dark grey slightly sandy, gravelly clay. Gravel is subangular to subrounded, fine to coarse of sandstone, clinker, coal and brick. Cobbles are subrounded of sandstone, mudstone and brick.
RH-HDP-25	Made Ground	0 – 1*	Brown, slightly gravelly sand/very dark brown gravelly sand. Gravel is angular to subrounded, fine to coarse of mudstone, coal, clinker and sandstone.

*Base of hand dug pit

4.3.1 Visual and Olfactory Observations

Two distinct types of Made Ground were observed across the site during the 2019 ground investigation, Made Ground associated with colliery spoil and Made Ground composed of unlicensed tipping waste (refuse). A hydrocarbon odour was recorded within the Made Ground of RH-BH05 at a depth of 7 – 9m bgl. No additional visual/olfactory evidence of gross contamination was identified in the remaining exploratory hole locations both within the Made Ground and natural deposits.

A site walkover, conducted during the setting out of the ground investigation works, identified a variety of wastes contained both within the eroding cliff face and on the foreshore. The types of wastes identified included colliery spoil, rubber tubing, plastics, rubble, glass, tiles and metals.

4.3.2 Groundwater Observations

Groundwater strikes were recorded within the Made Ground in four boreholes (RH-BH01, RH-BH02, RH-BH04 and RH-BH05) and one trial pit (TP07) at depths between 4.2m bgl (TP02) and 9m bgl (RH-BH02).

Three rounds of groundwater monitoring were undertaken on the 16th October, 31st October and 12th November 2019. Groundwater levels varied from 4.51m bgl to a maximum of 8.36m bgl. Groundwater levels recorded at each of the monitoring wells appeared to be generally consistent during all three monitoring rounds.

5 Human Health Risk Assessment

5.1 Assessment Methodology

5.1.1 Data Sources

An assessment of the data collected during the 2019 ground investigation and subsequent laboratory analysis was undertaken to determine if the ground conditions at the Lynemouth Coastal Landfill site represent a potential unacceptable risk to human health.

5.1.2 Assessment Criteria

Currently, RHDHV is unaware of any proposed development or plans for future development within the Lynemouth Coastal Landfill site. Therefore, Generic Assessment Criteria (GAC) for a public open space (park) end use has been used to screen the soil analytical data associated with the Lynemouth Coastal Landfill site. The CL:AIRE report (SP1010 – Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination, 2014) states that they key assumption for this model are as follows: the critical receptor is a child covering CLEA age classes 1-6 and exposure duration is 6 years (with the exception of contaminants where lifetime averaging applies (such as cadmium) where daily exposure is estimated for age classes 1-18 over 74 year duration; public park is grassed and may also contain landscaped areas and children's equipment; exposure pathways include direct soil ingestion, skin contact with soil, inhalation of vapours and of dust outdoors; there are no buildings; and land is predominantly grassed and not in close proximity to housing and thus tracking back of soil to the home is not considered a significant pathway.

Where GAC are exceeded this may indicate a potentially unacceptable risk to human health. Current GACs were collated from the LQM/CIEH S4ULs[7] and EIC/AGS/CL:AIRE GACs[8]. Where appropriate, reference has also been made to the Category 4 Screening Levels (C4SL)[9]. Where no published criterion has been identified, GACs have been derived by RHDHV using the deterministic CLEA v1.06 model. The toxicological data and physical/chemical input data (used to derive the GAC) were obtained from authoritative sources[10].

As well as the potential risk to human health from contaminants present within the soils, there is also potential risk to human health due to the migration of vapours from volatile PCOC within the groundwater. GAC derived by the Society of Brownfield Risk Assessment[11] have been used to screen volatile contaminants in groundwater.

Where a GAC for organic determinands is indicated to be above the soil saturation value, the saturation value has been adopted as the GAC. This follows the approach adopted by the EA for the derivation of the current Soil Guideline Values.

GAC have not been derived for a number of the PCOC particularly associated with the semi-volatile organic compounds, volatile organic compounds, pesticides and herbicide suites due to the lack of availability of robust physio/chemical data. Where GAC are not available the laboratory limit of detection has been utilised

[7] *Land Quality Press. 2015. The LQM/CIEH S4Uls for Human Health Risk Assessment*
[8] *CL:AIRE. 2010. Soil Generic Assessment Criteria for Human Health Risk Assessment*
[9] *CL:AIRE. 2014. SP1010 Development of Category 4 Screening Levels for Assessment of Land Affected by Contamination. Final Project Report (Revision 2)*
[10] *Environment Agency. 2008. Compilation of data for priority organic pollutants for derivation of Soil Guideline Values. Science Report: SC050021/SR7*
[11] *Society of Brownfield Risk Assessment. 2017. Development of Generic Assessment Criteria for Assessing Vapour Risks to Human Health Volatile Contaminants in Groundwater*

as a benchmark, and concentrations recorded above the LOD are included in the summary tables within this section.

Asbestos is not currently risk-assessed in the same way as chemical contaminants but is assessed on a 'presence' or 'absence' basis with progression to further quantification and detailed assessment where required. The CIRIA guidance for asbestos[12] in soil and Made Ground has been used to support this assessment.

5.2 Risk Estimation

5.2.1 Made Ground (Colliery Spoil)

The data assessment, including a plan showing the sample locations, is presented in Appendix D. A summary of the results is presented in Table 5-1. Only those samples exhibiting concentrations of PCOC greater than the GAC are summarised in the table. PCOC that were not detected above the GAC are not considered further in the assessment process.

Table 5-1: Summary of Results for Human Health Data Assessment for Made Ground (colliery spoil)

PCOC	Number of Samples Analysed	Number of Failures against GAC	Summary of Assessment Results
Asbestos	63	2	Bundles of chrysotile fibres were encountered within the Made Ground (colliery spoil) of TP16 (2.2m bgl), TP02 (4.9m bgl) at concentrations between 0.006% w/w and 0.009% w/w.
Arsenic	51	3	Three samples of the colliery spoil recorded concentrations of arsenic above the GAC of 170mg/kg, the samples were collected from RH-HDP-08A at a depth of 0.8m bgl, RH-HDP-18 at a depth of 0.8m bgl and RH-HDP-22 at a depth of 0.8m bgl. Concentrations recorded ranged from 180mg/kg to 220mg/kg. The arithmetic mean for arsenic is recorded as 34.86mg/kg, which is below the GAC value.
Lead	49	1	A single exceedance of GAC for lead (580mg/kg) was identified within the Made Ground colliery spoil deposits of RH-BH04 (1.5m bgl) l at a concentration of 1,600mg/kg. The arithmetic mean for lead is recorded as 103.6mg/kg, which is below the GAC value.

The arithmetic mean for all PCOC recorded within the colliery spoil were below their respective GAC values.

5.2.2 Made Ground (Refuse)

The data assessment, including a plan showing the sample locations, is presented in Appendix D. A summary of the results is presented in Table 5-2. Only those samples exhibiting concentrations of PCOC greater than the GAC are summarised in the table. PCOC that were not detected above the GAC are not considered further in the assessment process.

[12] *CIRIA. 2014. Asbestos in Soil and Made Ground: A Guide to Understanding and Managing Risks Associated with Asbestos.*

Table 5-2: Summary of Results for Human Health Data Assessment for Made Ground (refuse)

PCOC	Number of Samples Analysed	Number of Failures against GAC	Summary of Assessment Results
Asbestos	41	4	Bundles of chrysotile fibres were encountered within the Made Ground (refuse) of RH-BH05 (5m bgl & 6m bgl) and TP23 (2.55m bgl) at concentrations between <0.001% w/w and 0.017% w/w. A bundle of crocidolite was encountered within the Made ground of RH-BH05 (1.5m bgl) at a concentration of 0.001% w/w.
Benzo(b)fluoranthene	52	1	A single exceedance of GAC for benzo(a)fluoranthene (16mg/kg) was identified within the Made Ground refuse deposits of RH-BH05 at a depth of 7m bgl at a concentration of 29mg/kg. The arithmetic mean for benzo(b)fluoranthene is recorded as 0.85mg/kg, which is below the GAC value.
Benzo(a)pyrene	52	1	A single exceedance of GAC for benzo(a)pyrene (13mg/kg) was identified within the Made Ground refuse deposits of RH-BH05 at a depth of 7m bgl at a concentration of 32mg/kg. The arithmetic mean for benzo(a)pyrene is recorded as 0.94mg/kg, which is below the GAC value.
Dibenzo(a,h)anthracene	52	1	A single exceedance of GAC for dibenzo(a,h)anthracene (1.4mg/kg) was identified within the Made Ground refuse deposits of RH-BH05 at a depth of 7m bgl at a concentration of 4.7mg/kg. The arithmetic mean for dibenzo(a,h)anthracene is recorded as 0.22mg/kg, which is below the GAC value.

A strong hydrocarbon odour was noted in RH-BH05 at depths between 7m bgl and 9m bgl, this corresponds to the depths at which PAH compounds were identified within RH-BH05.

The arithmetic mean for all PCOC recorded within the refuse material were below their respective GAC values.

5.2.3 Natural Deposits

The data assessment, including a plan showing the sample locations, is presented in Appendix D. A summary of the results is presented in Table 5-3. Only those samples exhibiting concentrations of PCOC greater than the GAC are summarised in the table. PCOC that were not detected above the GAC are not considered further in the assessment process.

Table 5-3: Summary of Results for Human Health Data Assessment for Natural Deposits

PCOC	Number of Samples Analysed	Number of Failures against GAC	Summary of Assessment Results
Arsenic	27	6	Six exceedances of GAC for arsenic (170mg/kg) were identified within the natural deposits of RH-HDP-10 (0.2m bgl & 0.8m bgl), RH-HDP-16 (0.8m bgl), RH-HDP-19 (0.2 & 0.8m bgl) and RH-HDP-21 (0.2m bgl) at concentrations between 180mg/kg and 250mg/kg. The arithmetic mean for arsenic is recorded as 92.47mg/kg, which is below the GAC value.

The arithmetic mean for all PCOC recorded within the natural deposits were below their respective GAC values

5.3 Risk Evaluation

The risk estimation stage has indicated the presence of a limited number of potential contaminants of concern (PCOC) at concentrations exceeding the Generic Assessment Criteria (GAC) which may represent an unacceptable risk to sensitive receptors. The following sections further evaluate the potential risks to human health.

5.3.1 Asbestos

A total of 110 samples were scheduled for asbestos analysis. Bundles of chrysotile fibres were encountered at depths of 4.9m bgl within TP02, 2.2m bgl within TP16, 2.55m bgl within TP23 and at 5 and 6m bgl within RH-BH05. A bundle of crocidolite was encountered at a depth of 1.5m bgl within RH-BH05. Made Ground was encountered within these exploratory locations and is likely to be the source of the asbestos, although asbestos containing material was not observed during the ground investigation at these locations. During the site walkovers and observations made on site asbestos containing material in the form cement bound asbestos fragments were observed on the foreshore in the form of pebbles.

There are no assessment criteria for asbestos, underlying the principle that there is no safe level of exposure. Most of the guidance relating to asbestos is associated with the management of asbestos in buildings and occupational exposure. However, CIRIA[13] has published guidance to aid in the assessment of asbestos in the ground and has been referred to in the compilation of this report.

It should be noted that asbestos only presents a risk to human health if: (i) fibres become airborne and are released into the atmosphere; and (ii) people become exposed to such airborne dust. Existing guidance notes that exposure to even limited amounts of asbestos can have determinantal health effects. The release of asbestos fibres into the air is influenced by a number of site-specific factors, e.g. soil type and characteristics, site characteristics and land use, as described in Table 5-4.

Table 5-4: Factors affecting fibre release

Parameter	Discussion
Limit of detection used during analysis	The CIRIA report references ICRCL guidance which states that 'a concentration of 0.001% (of asbestos in soil) is cited as a level potentially able to generate significant airborne fibre concentrations. So, further investigation or assessment is justified above this level'. It is also recommended as a minimum limit of detection for soil analysis. However, it should be noted that it is not a level below which ICRCL deem that risks relating to asbestos are acceptable or below which potential civil liabilities could be assumed to be negligible. Therefore, it is not an appropriate GAC value for asbestos containing materials (ACMs). The laboratory analysis has adopted a limit of detection of 0.001% w/w, six samples identified as containing asbestos recorded a concentration above this value.
Wind action	Wind action can release fine respirable dust particles and asbestos fibres from soil surfaces when dry. The main factors affecting the release of fibres via wind action are weather and level/type of vegetation. The site is predominantly covered with grasses with the cliff faces left exposed and without a vegetation covering. Footpaths, both designated and ones created by members of the public walking across the site, are present. The asbestos identified within the samples analysed were located at depths greater than 1.5m bgl. A total of 55 shallow soil samples (collected at depths no greater than 1m bgl) were collected from

[13] *CIRIA. 2014. Asbestos in Soil and Made Ground: A Guide to Understanding and Managing Risks Associated with Asbestos.*

Parameter	Discussion
	across the site and tested for asbestos, asbestos was not identified within any of these samples. Due to the location of the site, it is assumed likely to be exposed to windy weather, this in addition to the erosion of the cliff face which is currently occurring. The act of erosion increases the risk of asbestos that is currently buried becoming exposed and being deposited onto the foreshore.
Activities that damage the vegetation and soil surface	Activities such as BMX type cycling and quad bike racing can damage vegetation and the soil surface and potentially result in the release of asbestos fibres if present. However, the depths at which asbestos has been identified at a depth greater than 1.5m bgl and therefore unlikely to release fibres if damage occurred to surface soils. Given the current use of the site as an area of public open space, it is reasonable to expect at certain times of year, and during periods of good weather, there will be increased usage of the site. With increased usage, there is increased potential for damage to vegetation and soils to occur, however as above, the asbestos has been identified at a depth greater than 1.5m bgl and therefore unlikely to release fibres if damage occurred to the surface soils via this method.
Burrowing animals	Burrowing animals can bring asbestos to the surface if present. Whilst this is a potential risk activity, the presence of asbestos is limited and at depths greater than 1.5m bgl. As burrowing animals have the ability to bring asbestos bound in cement fragments to the surface and also the loose fibres identified within soil, although the presence of asbestos is not extensive across the site, this activity has the potential to give rise to unacceptable risks.
Soil type	CIRIA guidance refers to a laboratory study undertaken by Addison et al in 1988 regarding fibre release. The study showed that for a given asbestos type, a clay soil released less asbestos fibre than any other soil type. The soils across the Lynemouth Coastal Landfill site have been investigated through an intrusive ground investigation which confirmed that at the locations where asbestos was identified, the soil type was generally recorded as gravelly sands/slightly clayey gravelly sands. This was also true across the site. This soil type has the potential to release asbestos fibres present to be liberated more easily than if the site comprised a clay rich soil.
Asbestos type	CIRIA guidance refers to a laboratory study undertaken by Addison et al in 1988 regarding fibre release. The study showed that for a given type of soil, crocidolite was released more readily than amosite which in turn was released more readily than chrysotile. Five of the soils identified as containing asbestos contained chrysotile, one sample contained crocidolite.
Moisture content	CIRIA guidance refers to a laboratory study undertaken by Addison et al in 1988 regarding fibre release. The study demonstrated that the release of airborne asbestos fibres was strongly influenced by soil moisture content. The study illustrated that the addition of 5% moisture resulted in a reduction of airborne asbestos by 80 - 90%. Soil moisture content was not assessed as part of the 2019 ground investigation. However, it should be noted that moisture content will be seasonally variable within the site and thus at certain times of the year, e.g. summer, when the ground is drier the potential for asbestos fibres to be liberated from the Made Ground increases. Should fibres be released by the eroding cliff edge via wave and tidal action it is likely that the fibres will be washed into the sea adjacent to the site. Therefore, the fibres are not within the air which is the pathway for asbestos to be exposed to human health. The sea potentially acts as a method of abatement.

At the time of writing, there are currently no plans to redevelop the Lynemouth Coastal Landfill site. However, the presence of asbestos may pose an unacceptable risk to construction and/or maintenance workers should future development at the site occur. However, this risk can be easily mitigated against should development occur.

Currently, the site is utilised as an area of public open space including the beach area on which the eroding cliff face is depositing waste. The ground investigation has identified the presence of asbestos (as loose fibres) in the Made Ground, at locations along the eastern edge of the site. The ongoing erosion of the cliff face is also releasing occasional cement-bound asbestos fragments. Such fragments have been observed on the foreshore as pebbles. The breakdown via diagenesis and erosion processes of the cement-bound asbestos fragments is understood to cause the liberation the asbestos fibres which has the potential to pose an unacceptable risk to the general public who currently use the site.

5.3.2 Arsenic

Nine samples, three Made Ground and six natural deposits, exceeded the GAC for arsenic. The samples were recovered from the shallow deposits of RH-HDP-08A, RH-HDP-18 and RH-HDP-22 (Made Ground – colliery spoil) and RH-HDP-10, RH-HDP-16, RH-HDP-19 and RH-HDP-21 (natural deposits). The concentrations recorded for all samples were above the laboratory limit of detection (mean concentration 42.54mg/kg) and were generally above that of background levels recorded by the BGS[14] which range between 8.07mg/kg and 9.08mg/kg.

The mean concentration for arsenic is significantly lower than the respective GAC. The exceedances of the GAC which have been recorded are considered to be marginal exceedances and are unlikely to pose an unacceptable risk to human health or a major restraint to the redevelopment of the site in the future.

5.3.3 Lead

One sample analysed exceeded the GAC for lead, the sample which was collected at a depth of 1.5m bgl within RH-BH04 recorded a concentration of 1600mg/kg. The exploratory hole log describes the soil as Made Ground with sandstone, clinker, brick and coal. The concentrations recorded within the samples analysed were all above the laboratory limit of detection (mean concentration 80.33mg/kg) and were generally above that of background levels recorded by the BGS which range between 33.2mg/kg and 47.1mg/kg.

The mean concentration for lead is significantly lower than the respective GAC and so lead concentrations are unlikely an unacceptable risk to human health or a major constraint to redevelopment of the site in the future.

5.3.4 Benzo(b)fluoranthene

One sample analysed exceed the GAC for benzo(b)fluoranthene, the sample which was collected at a depth of 7m bgl within RH-BH05 recorded a concentration of 29mg/kg. The exploratory hole log describes the soil as Made Ground with sandstone and coal gravels. 31 of the 156 soil samples analysed recorded concentrations of benzo(b)fluoranthene above the laboratory limit of detection, the mean concentration of the samples above the laboratory limit of detection is recorded as 0.38mg/kg.

The mean concentration for benzo(b)fluoranthene is significantly lower than the respective GAC and so concentrations of benzo(b)fluoranthene recorded are unlikely to pose an unacceptable risk to human health or a major constraint to the redevelopment of the site in the future.

[14] *British Geological Survey – Contaminant Distribution in Soil. Available online (mapapps2.bgs.ac.uk/bccs/home.html)*

5.3.5 Benzo(a)pyrene

One sample analysed exceed the GAC for benzo(a)pyrene, the sample which was collected at a depth of 7m bgl within RH-BH05 recorded a concentration of 32mg/kg. The exploratory hole log describes the soil as Made Ground with sandstone and coal gravels. 34 of the 156 soil samples analysed recorded concentrations of benzo(a)pyrene above the laboratory limit of detection, the mean concentration of the samples above the laboratory limit of detection is recorded as 0.42mg/kg.

The mean concentration of benzo(a)pyrene is significantly lower than the respective GAC and so concentrations recorded in the samples analysed indicate that it is unlikely to pose an unacceptable risk to human health or act as a major constraint to the redevelopment of the site in the future.

5.3.6 Dibenzo(a,h)anthracene

One sample analysed exceed the GAC for dibenzo(a,h)anthracene, the sample which was collected at a depth of 7m bgl within RH-BH05 recorded a concentration of 4.7mg/kg. The exploratory hole log describes the soil as Made Ground with sandstone and coal gravels. 15 of the 156 soil samples analysed recorded concentrations of dibenzo(a,h)anthracene above the laboratory limit of detection, the mean concentration of the samples above the laboratory limit of detection is recorded as 0.14mg/kg.

The mean concentration of dibenzo(a,h)anthracene is significantly lower than the respective GAC and so the concentrations recorded indicate that it is unlikely to pose an unacceptable risk to human health or act as a major constraint to the redevelopment of the site in the future.

6 Interim Controlled Waters Risk Assessment

6.1 Data Sources

The data assessment includes an assessment of groundwater analytical results from three rounds of groundwater samples recovered in October/November 2019 and an assessment of the surface water analytical results from one round of surface water samples recovered in October 2019.

The Environment Agency has recommended that further rounds of groundwater and surface water sampling are undertaken as the project progresses through its next stages. These data would then be analysed and the results interpreted to enable an update of the 'interim' controlled waters risk assessment that is presented in this section.

6.2 Conceptual Site Model

6.2.1 Hydrogeology

Data contained within the Envirocheck report for the Lynemouth Coastal Landfill site indicates that both the superficial deposits, which comprise Blown Sand, Marine Deposits and Till, and the underlying Pennine Middle Coal Measures Formation are classified as Secondary A Aquifers. These types of aquifer are composed of permeable layers capable of supporting water supplies at a local rather than a strategic scale, and in some cases forming an important source of base flow to rivers.

The ground investigation across the Lynemouth Coastal Landfill site indicated that the geological strata at the site comprises Made Ground (including colliery spoil and refuse material) overlying natural sand and gravel deposits. Bedrock strata (Sandstone) was encountered at the base of borehole excavations at several locations. Groundwater was encountered within the Made Ground at five locations

The groundwater levels observed during the ground investigation indicate that the shallow groundwater flow is to the east towards the North Sea.

The Lynemouth Coastal Landfill site is not located within a Source Protection Zone (SPZ) and no potable water abstractions are recorded within 1km of the site. The nearest licensed groundwater abstraction to the site is located 640m south-west, the groundwater is recorded as being utilised for remediation works at Lynemouth Colliery Mine Shaft Site. However, the permit is recorded as expiring in June 2018. The location of the site suggests that there may be an element of connectivity between groundwater bodies and the saline sea water creating a brine interface which is likely to restrict the uses of abstracted water within the surrounding area. In addition to this, the potential connectivity between the two waterbodies could result in contaminants within the groundwater of the site migrating into the North Sea and potentially impacting a wider area.

6.2.2 Hydrology

The River Lyne is located within the southern part of the Lynemouth Coastal Landfill site and flows in a southerly to easterly direction towards the North Sea. The River Lyne from its source to the tidal limit (waterbody ID GB103022076820) is recorded on the Environment Agency Catchment Data Explorer[15] as having an overall classification of poor water quality and poor ecological quality (2016).

[15] *Environment Agency – Catchment Data Explorer (http://environment.data.gov.uk/catchment-planning/WaterBody/GB103022076820)*

The northern end of the site is located within the Northumbria Coast Ramsar Site. To the south of the site is the Northumberland Coast Special Protection Area and to the east the North Sea, which the River Lyne drains into, is a designated Marine Conservation Zone.

Three mine water treatment lagoons are located to the immediate south of the site, the North Sea is located to the east.

There are no licensed abstractions from surface water within the site boundary.

6.3 Critical Receptor

For the purpose of undertaking the controlled waters risk assessment surface waters have been considered to be the critical receptor based on the following rationale:

- The Secondary A Aquifers associated with the superficial deposits (where present) and the bedrock strata (Pennine Middle Coal Measures Formation). It is possible that the River Lyne is hydraulic continuity with the shallow groundwater encountered on the site;
- Based on the information available there does not appear to be any potable water abstractions from the Second A Aquifers within the site.

6.4 Assessment Methodology

The assessment of risks to controlled waters has comprised an interim Generic Quantitative Risk Assessment (GQRA) in which dissolved phase contaminant concentrations have been compared to Generic Assessment Criteria appropriate to the identified 'critical receptor'. Substances recorded at concentrations greater than a GAC have been listed as PCOC pending further assessment (where deemed necessary); further assessment may require *inter alia* the collection of additional field data with the objective of refining the CSM.

6.5 Generic Assessment Criteria

The applicable GACs are deemed to be Water Framework Directive (WFD) Environmental Quality Standards (EQS). For substances without a published EQS and in accordance with industry practice, GACs are based on the following, in order of preference:

- Water Environment Regulations 2015 surface water EQS[16]
- For petroleum hydrocarbon fractions – laboratory limit of detection (LOD)
- For benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene and indeno(1,2,3-cd)pyrene - benzo(a)pyrene has been used as a marker
- Where no assessment criteria are available, reference has been made to the laboratory LOD

6.6 Groundwater

6.6.1 Risk Estimation

The data assessment is presented in Appendix C and a summary of the results are presented in Table 6-1.

Only those samples exhibiting concentrations of PCOC greater than the GAC are summarised in the table. PCOC that were not detected above the GAC are not considered further in the assessment process.

[16] *The Water Environment (Water Framework Directive) (England and Wales) (Amendment) Regulations 2015 (Statutory Instrument) (http://www.legislation.gov.uk/uksi/2015/1623/2015-09-14)*

Table 6-1: Summary of Results for Controlled Water s (Groundwater) Data Assessment

PCOC	Number of samples analysed	Number of failures against GAC/>LOD	Summary of assessment results
Note: *no GAC, concentrations exceed LOD			
Barium	5	5*	No EQS; maximum concentration of 40µg/l was recorded in RH-BH02, above the LOD of 0.26µg/l. The arithmetic mean for barium was recorded as 28.2µg/l, which exceeded the LOD value.
Boron	5	5*	No EQS; maximum concentration of 3000µg/l was recorded in RH-BH01, above the LOD of 12µg/l. The arithmetic mean for boron was recorded as 1184µg/l, which exceeded the LOD value.
Cadmium	5	5	Four groundwater samples recorded cadmium concentrations above the GAC value of 0.2µg/l. Concentrations recorded ranged from 0.17µg/l (RH-BH01) to 1.3µg/l (RH-BH04). The arithmetic mean for cadmium was recorded as 0.55µg/l which exceeded the GAC value.
Copper	5	5	One groundwater sample recorded copper concentrations above the GAC value of 3.76µg/l (RH-BH02). The arithmetic mean for copper was recorded as 2.92µg/l, which did not exceed the GAC value.
Nickel	5	5	All five groundwater samples recorded nickel concentrations above the GAC value of 8.6µg/l. Concentrations recorded ranged from 17µg/l (RH-BH02) to 460µg/l (RH-BH01). The arithmetic mean for nickel was recorded as 135.2µg/l, which exceeded the GAC value.
Selenium	5	3*	No EQS; maximum concentration of 3.4µg/l was recorded in RH-BH04, above the LOD of 0.25µg/l. The arithmetic mean for selenium, was recorded as 1.192µg/l, which is above the LOD value.
Vanadium	5	5*	No EQS; maximum concentration of 3µg/l was recorded in RH-BH01, above the LOD of 0.6µg/l. The arithmetic mean for vanadium was recorded as 2.32µg/l, which is above the LOD value.
Acenaphthene	5	1*	No EQS; maximum concentration of 0.02µg/l was recorded in RH-BH05, above the LOD of 0.01µ/l. The arithmetic mean for acenaphthene was recorded as 0.012µg/l, which is above the LOD value.
Fluorene	5	1*	No EQS; maximum concentration of 0.02µg/l was recorded in RH-BH05, above the LOD of 0.01µ/l. The arithmetic mean for fluorene was recorded as 0.012µg/l, which is above the LOD value.

PCOC	Number of samples analysed	Number of failures against GAC/>LOD	Summary of assessment results
Fluoranthene	5	2	Two groundwater samples exceeded the GAC for fluoranthene (0.0063µg/l). The samples collected from RH-BH04 and RH-BH05 recorded concentrations of 0.02µg/l and 0.05µg/l respectively. The arithmetic mean for fluoranthene was recorded as 0.02µg/l, which exceeds the GAC value.
Phenanthrene	5	1*	No EQS; maximum concentration of 0.04µg/l was recorded in RH-BH05, above the LOD of 0.01µ/l. The arithmetic mean for phenanthrene was recorded as 0.016µg/l, which is above the LOD value.
Pyrene	5	3*	No EQS; maximum concentration of 0.07µg/l was recorded in RH-BH05, above the LOD of 0.01µg/l. The arithmetic mean for pyrene was recoded as 0.032µg/l, which is above the LOD value.
Benzo(a)anthracene	5	1*	No EQS; maximum concentration of 0.02µg/l was recorded in RH-BH05, above the LOD of 0.01µg/l. The arithmetic mean for benzo(a)anthracene was recorded as 0.012µg/l, which is above the LOD value.
Benzo(b)fluoranthene	5	1	A single exceedance of the GAC for benzo(b)fluoranthene (0.00017µg/l) was recorded within RH-BH05. The concentration recorded was 0.01µg/l. The arithmetic mean for benzo(b)fluoranthene was recorded as 0.01µg/l, which exceeds the GAC value,
Benzo(k)fluoranthene	5	1	A single exceedance of the GAC for benzo(k)fluoranthene (0.00017µg/l) was recorded within RH-BH05. The concentration recorded was 0.02µg/l. The arithmetic mean for benzo(k)fluoranthene was recorded as 0.012µg/l, which exceeds the GAC value.
Benzo(g,h,i)perylene	5	1	A single exceedance of the GAC for benzo(g,h,i)perylene (0.00017µg/l) was recorded within RH-BH05. The concentration recorded was 0.01µg/l. The arithmetic mean for benzo(g,h,i)perylene was recorded as 0.01µg/l, which exceeds the GAC value.
Chrysene	5	1*	No EQS; a maximum concentration of 0.03µg/l was recorded at RH-BH05, above the LOD of 0.01µg/l. The arithmetic mean for chrysene was recorded as 0.014µg/l, which is above the LOD value.
Phenol – monohydric	5	1*	No EQS; a maximum concentration of 230µg/l was recorded at RH-BH01, above the LOD of 100µg/l. The arithmetic mean for phenol – monohydric was recorded as 126µg/l, which is above the LOD value.
1,2,4-trimethylbenzene	5	1*	No EQS; a maximum concentration of 2µg/l was recorded at RH-BH01, above the LOD of 1µg/l.

PCOC	Number of samples analysed	Number of failures against GAC/>LOD	Summary of assessment results
			The arithmetic mean for 1,2,4-trimethylbenzene was recorded as 1.2µg/l, which is above the LOD value.

The limit of detection was greater than the GAC for the following contaminants:

- Fluoranthene;
- Benzo(b)fluoranthene;
- Benzo(k)fluoranthene;
- Benzo(a)pyrene;
- Indeno(1,2,3-c,d)pyrene;
- Benzo(g,h,i)perylene; and
- Pentachlorophenol.

Upon review of the above interim findings, the Environment Agency has recommended that further sampling, laboratory analysis and assessment be undertaken and interpreted within the context of an updated Controlled Waters Assessment. This will be undertaken as the project progresses to future stages.

6.7 Surface Water

6.7.1 Risk Estimation

The data assessment is presented in Appendix C. A summary of the results is provided below.

Metals

Metals were generally not detected at concentrations exceeding the WFD criteria for inland waters (2015) in surface water samples collected during the 2019 ground investigation. Cadmium, copper and nickel were detected at concentrations exceeding the assessment criteria. Copper was the most prevalent, being detected in four of the five samples (SW1, SW2, SW3 and SW4) at concentrations ranging from 1.7µg/l to 6.7µg/l which exceed the assessment criteria value of 1µg/l.

Nickel was recorded at concentrations exceeding the assessment criteria of 4µg/l in SW1(4.4µg/l) and SW5 (19µg/l).

Cadmium was recorded at a concentration exceeding the assessment criteria of 0.08µg/l in SW1 (0.09µg/l).

The laboratory limit of detection for hexavalent chromium was greater than that of its respective assessment criteria and so it could not be determined whether exceedances for this PCOC were present in the samples analysed.

With the exception of copper and nickel, the metals analysed within the surface waters has arithmetic means below the relevant GAC. Both copper and nickel exceeded the GAC with arithmetic means of 3.98mg/kg and 6.36mg/kg respectively.

Cyanide

The laboratory limit of detection for cyanide (total) was greater than that of its respective assessment criteria and so it could not be determined whether exceedances for this PCOC were present in the samples analysed.

TPH

Hydrocarbons were detected in SW4 at concentrations exceeding the assessment criteria for aliphatics C10-C12 (18µg/l – GAC 1µg/l), C12-C16 (2.8µg/l – GAC 1µg/l), C21-C25 (56µg/l – GAC 1µg/l) and C5-C35 (67µg/l – GAC 10µg/l). Hydrocarbons were not recorded above the laboratory limit of detection in the remaining samples analysed.

PAH

PAH was only detected at concentrations exceeding the assessment criteria in SW5. The exceedance relates to benzo(a)pyrene and was recorded at a concentration of 0.03µg/l with the GAC determined as 0.00017µg/l.

The laboratory limit of detection for fluoranthene, benzo(a)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, benzo(g,h,i)perylene and PAH total were greater than that of its respective assessment criteria and so it could not be determined whether exceedances for these PCOC were present in the samples analysed.

Upon review of the above interim findings, the Environment Agency has recommended that further sampling, laboratory analysis and assessment be undertaken and interpreted within the context of an updated Controlled Waters Assessment. This will be undertaken as the project progresses to future stages.

6.8 Risk Evaluation

Possible risks to controlled waters are considered to derive from the potential for leaching of contaminants in the Made Ground into the groundwater and the subsequent horizontal and vertical transport via groundwater flow with the potential to impact both the River Lyne (on-site) and the North Sea (off-site), designated aquifers and associated abstractions and the wider groundwater resource.

The calculated salinity of the groundwater samples collected from the boreholes within the site indicates that the groundwater is in hydraulic connectivity with the North Sea to the east. Groundwater flows indicate that, generally, the flow direction is to the east, again towards the North Sea rather than towards the River Lyne and so it is considered to be the receptor most at risk from migration of contaminants from the site. However, this assessment is based on a limited data set with data collected within a short period of time and it is likely that the groundwater flows within the site are more complex with flows potentially influenced by the local tidal regime and seasonality.

As previously noted, Environment Agency has recommended that further sampling, laboratory analysis and assessment be undertaken and interpreted within the context of an updated Controlled Waters Assessment. This will be undertaken as the project progresses to future stages.

7 Ground Gas Monitoring and Assessment

This section presents gas monitoring undertaken as part of the 2019 ground investigation across the Lynemouth Coastal Landfill site.

7.1 Conceptual Site Model

The key gas source within the Lynemouth Coastal Landfill site is considered to be the areas associated with Made Ground (refuse). The Lynemouth Coastal Landfill site has historically been subject to both legal and illegal tipping of materials. At the time of writing there are no plans to develop the site and thus the current land use of public open space remains unchanged.

Based on historical data, intrusive investigations undertaken to date and anecdotal information from Northumberland County Council, it appears that within the Lynemouth Coastal Landfill site both colliery spoil and other wastes (including permitted commercial and household waste) are present. Between 2002 and 2004 reclamation works saw the removal of existing colliery and other wastes to the historic 1924 shoreline. The excavated materials were buried on site in an unlined pit excavated within the sand dunes, the sand removed during this process was used to form a 0.5m capping later above the pit.

7.2 Approach to Assessment

Combined groundwater and ground gas monitoring wells were installed during the 2019 ground investigation with the response zones targeting Made Ground, natural deposits or both.

7.3 Ground Gas Monitoring

7.3.1 Methane

Methane was not detected during the three monitoring rounds undertaken as part of the 2019 ground investigation.

7.3.2 Carbon Dioxide

Carbon dioxide concentrations ranged from 0.1% v/v to a maximum concentration of 14% v/v. Carbon dioxide concentrations were noted to fluctuate across all monitoring rounds at each location, with the exception of RH-BH02, RH-BH04, RH-BH08 and RH-BH09 were concentrations remained fairly constant during all monitoring rounds.

A maximum concentration of 14% v/v was recorded at RH-BH03 during the first two monitoring rounds but dropped to 2.5% v/v during the third round but does not appear to correlate with atmospheric pressure.

7.3.3 Oxygen

Oxygen concentrations ranged from 0.7% v/v to 20.50% v/v. Oxygen concentrations were noted to fluctuate across all monitoring rounds at each location and does not appear to correlate with atmospheric pressure.

7.3.4 Carbon Monoxide

Carbon monoxide was not detected during the three monitoring rounds undertaken as part of the 2019 ground investigation.

7.3.5 Hydrogen Sulphide

Hydrogen sulphide was not detected during the three monitoring rounds undertaken as part of the 2019 ground investigation.

7.3.6 Barometric Pressure

Barometric pressure ranged from 987mb to 1022mb. The final monitoring round exhibited the lowest pressure. There does not appear to be any correlation between pressure and recorded concentrations.

7.3.7 Flow

Flow rates were not detected in the boreholes monitored during the 2019 ground investigation.

7.3.8 Depth to Water

Groundwater levels were recorded during each of the gas monitoring rounds. Groundwater levels ranged from 4.51m bgl to 8.36m bgl. RH-BH06, RH-BH08 and RH-BH09 were each recorded as dry during the three monitoring rounds conducted.

7.4 Risk Evaluation

An assessment of ground gas results in order to produce a series of Gas Screening Values (GSV) in accordance with CIRIA guidance (CIRIA C665[17]) has not been undertaken as this was not considered appropriate as the site is retaining its current use as public open space rather than being redeveloped within infrastructure that may or may not require gas protection measures.

A review of the ground gas monitoring undertaken as part of the 2019 ground investigation did not generally record significantly elevated ground gas concentrations or any gas flow. From the data assessed, there does not appear to be any correlation between barometric pressure, flow rates or gas concentrations recorded.

The results of monitoring and assessment of the results have indicated that with respect to risk posed by ground gas the site is considered to be very low risk to both current site users and residential/commercial properties located adjacent to the site.

[17] *CIRIA. 2007. Assessing Risks Posed by Hazardous Ground Gases to Buildings.*

8 Updated Conceptual Site Model

Following a review of the PCSM and the completion of the 2019 ground investigation, an update to the PCSM and Qualitative Assessment has been undertaken. The update considers if feasible pollutant linkages exist and assesses to determine whether it could represent an unacceptable risk to human health or controlled waters. The updated conceptual site model and generic quantitative risk assessment are presented in Table 8-1.

Table 8-1: Conceptual Site Model and Qualitative Risk Assessment

Source	Pathway	Receptor	Qualitative Assessment
Landfill – waste materials and Made Ground	Dermal contact, ingestion and inhalation	Human health – current site users	Public access to the beach and dunes is possible and could present a direct exposure pathway to human health from potentially contaminated materials. However, with the exception of isolated occurrences of asbestos, the assessment of the 2019 ground investigation data identified that as a whole the arithmetic mean for PCOC were below the relevant GAC. Erosion of landfill materials onto the beach frontage has led to waste materials and other potential sources of contamination, including asbestos, becoming present within sediments and beach sands.
	Migration of ground gas	Human health – current users	Ground gas monitoring was conducted as part of the 2019 ground investigation, an assessment of the data concluded that there was a very low risk. Gas generating waste materials were not encountered during the intrusive ground investigation works.
	Dissolution into pore water/shallow groundwater and subsequent migration	Human health – current site users	There is potential for contaminants to be present in dissolved phases issuing onto the beach frontage. As a result, human health can be affected by exposed contact with contaminated waters seeping onto the beach. Although PCOC were detected above GAC values at some locations within the soils and groundwaters the majority of samples had arithmetic means below the related GAC values and are thus considered to pose a limited risk to human health receptors. However, leachate tests were not conducted as part of the 2019 ground investigation, therefore there is some uncertainty as to how this could potentially impact human health receptors,
	Erosion	Controlled waters – surface waters	Landfill wastes and soils can be distributed across the site by coastal processes. Direct entry of materials into surface waters present on site has been observed and is known to have occurred. This has the potential to pose a risk to water quality and the ecological health of that waterbody.
	Direct contact with unlined landfills – leaching and migration	Controlled waters – groundwater and surface waters	The 2019 ground investigation did not identify evidence of a liner between the Made Ground deposits and natural deposits and so there is the potential for PCOC to leach from the overlying soils and migrate to controlled waters. Although PCOC were detected above GAC values at some locations within the soils and groundwaters the majority of samples had arithmetic means below the related GAC values and are thus considered to pose a limited risk to controlled waters. However, leachate tests were not conducted as part of the 2019 ground investigation, therefore

Source	Pathway	Receptor	Qualitative Assessment
			there is some uncertainty as to how this could potentially impact controlled waters.
Contaminated sediments and beach materials	Dermal contact, ingestion and inhalation	Human health – current site users	Erosion of landfilled materials onto the beach frontage has led to waste materials and other potential sources of contamination becoming present within the sediments and beach sands. With the exception of isolated occurrences of asbestos, the assessment of the 2019 ground investigation data identified that as a whole the arithmetic mean for PCOC within soils were below the relevant GAC. However, natural beach sediments were not tested as part of the 2019 ground investigation and so there is the potential for PCOC to be present at unacceptable levels following erosion from the cliff face.
	Direct contact – dermal, ingestion and inhalation	Ecological health	Contaminated sediment and beach deposits may present a hazard to ecological health.
Colliery spoil	Direct contact – dermal, ingestion and inhalation	Human health – current site users	Analysis of the chemical data for colliery spoil from the 2019 ground investigation indicated that although there were exceedances recorded for arsenic and lead, the arithmetic mean for both of these PCOC and other PCOC analysed and was therefore considered as a low risk for human health receptors. However, asbestos has been identified within the colliery spoil which may present an unacceptable risk to human health receptors.
	Direct entry – erosion	Controlled waters – surface waters	Landfill wastes and soils can be distributed across the site by coastal processes. Direct entry of materials into surface waters present on site has been observed and is known to have occurred.
	Leaching through unsaturated and saturated soils	Controlled waters – surface waters and groundwater	The current interaction of the landfill site with surface waters and groundwaters could represent an unacceptable risk. Although the arithmetic mean was generally lower than their respective GAC within groundwater samples tested, there was limited coverage across the site and so PCOC t higher concentrations may be present in other areas of the site. Leachate tests were not conducted as part of the 2019 ground investigation, therefore there is some uncertainty as to how this could potentially impact controlled waters.
Discharges of waters	Direct contact - dermal, ingestion and inhalation	Human health – current site users	Mine water discharges could be associated with elevated hazardous chemicals. Risks to human health receptors can develop from direct exposure and contact with these discharges. Public access to the beach and these streams and surface waters is possible.
	Direct entry	Controlled waters – surface waters	Mine water discharges which are discharged directly into the surrounding surface water bodies could be associated with elevated hazardous chemicals. Although elevated PCOC were not found to be elevated in all surface water samples analysed as part of the 2019 ground investigation, it is possible that it still represents an unacceptable risk to surface water bodies.

It should be noted that all findings above relating to controlled waters should be treated as ‘interim’ because the Environment Agency has recommended that further sampling, laboratory analysis and assessment be

undertaken and interpreted within the context of an updated Controlled Waters Assessment. This will be undertaken as the project progresses to future stages.

8.1 Summary of Risks

The updated conceptual site model and generic quantitative risk assessment have established feasible pollution linkages at the site still exist following the refinement of the model. These linkages may present potentially unacceptable risks to property, human health and controlled water. These are summarised as follows:

- Current site users;
- Adjacent site users;
- Controlled waters (surface waters);
- Controlled waters (groundwaters); and
- Ecological receptors.

9 Conclusions and Recommendations

9.1 Conclusions

Northumberland County Council is conducting a feasibility study into the options available to manage the risks from eroding colliery spoil and waste materials from the cliffs at Lynemouth Bay, Northumberland. Further development and change of use of the site from its current use as public open space is currently not proposed.

Royal HaskoningDHV (RHDHV) was previously commission by Northumberland County Council to carry out a desk based contaminated land study, the findings of which confirmed the need for an intrusive investigation in order to clarify the risks associated with the potential pollutant linkages identified during the desk study. As such RHDHV was commissioned to develop and implement a single phase of site characterisation works to help inform the feasibility study. The findings of the study undertaken are presented in the preceding sections of this report.

Whilst the assessment has identified a limited number of PCOC in the soils, groundwater and surface waters analysed, it is considered unlikely that they represent a significant possibility of significant harm. This assessment has been undertaken with respect with current site use (public open space). Those results pertaining to controlled waters (both groundwaters and surface waters) should be treated as interim because the Environment Agency has recommended that further sampling, laboratory analysis and assessment be undertaken and interpreted within the context of an updated Controlled Waters Assessment. This will be undertaken as the project progresses to future stages.

It should be noted that the risks from plastics and the refuse waste were not assessed as part of the human health risk assessment, however the risk remains to the amenity of the area and to sensitive ecological receptors on and adjacent to the site from refuse waste in areas where erosion is actively taking place. Quantifying this risk is difficult because: (i) the bay has largely already been despoiled by deposition of colliery spoil and so ecological and landscape value is already lower than under natural conditions; and (ii) there are no known GAC for ecotoxicological effects on habitats and species in the marine environment. Indeed, this is the subject of ongoing innovative research funded by the Natural Environment Research Council (NERC) which started in 2020 and is scheduled to run over the next three years. In the meantime, the general principle is that release of plastics, rubbers and other refuse waste onto the beach and into the marine environment is likely to cause some degree of harm to both the landscape character of the area, and to any ecological receptors that come into contact with the waste, and so should ideally be avoided.

9.2 Recommendations

The findings of this interim Generic Quantitative Risk Assessment are being used to inform the feasibility study to manage the risks from eroding colliery spoil and waste materials from the cliffs of Lynemouth Bay. Northumberland County Council has stated its commitment to tackling the issue and as the project progresses, it is recommended that further sampling, laboratory analysis and assessment be undertaken of controlled waters (both groundwaters and surface waters) in line with Environment Agency advice. These results should then be interpreted within the context of an updated Controlled Waters Assessment which should be undertaken as the project progresses to future stages of design and consenting.

It is also recommended that pre application advice is sought from the Environment Agency with respect to the Environmental permitting requirements to support options of the feasibility study.

Appendix A - Figures

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Appendix B - Dunelm Factual Report

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Appendix C - Laboratory Certificates – Soil Chemistry

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Appendix D - Screened Chemical Data

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Appendix E - Limitations

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Limitations

This report has been prepared by Royal HaskoningDHV with reasonable skill and care, within the terms of the contract with the Client.

The direct assessments and judgements given in this report are limited by both the finite data on which they are based and the proposed works to which they are addressed. The report has utilised a variety of publicly available data sources therefore the study is limited by the age and limitations inherent in the data. The acquisition of data is also constrained by both physical and economic factors and by definition is subject to the limitations imposed by the methods of investigations employed. In this instance the data has been obtained from samples and tests from mechanically drilled boreholes and mechanically excavated trial pits which by their nature only provide information about small discrete volumes of soil. They cannot provide data on every section of the ground beneath the site, but the data are taken to be spatially representative of the zones of material between exploratory hole locations.

Conditions at the site will change over time due to natural variations and may be affected by human activities. In particular, groundwater, surface water and soil gas conditions should be anticipated to change with diurnal, seasonal and meteorological variations. Soil and water chemistry may change due to the actions of groundwater flows and microbiological activity etc. The likely variations in the data with time can be assessed following extended periods of measurement and statistical analyses. Unless specifically discussed in the text such extended measurement and analysis have not been carried out and the data collected are taken to be representative.

This document has been prepared for the titled project and should not be relied upon or used for any other project. This document is confidential and has been prepared for the sole benefit of the Client. Royal Haskoning accepts no responsibility or liability for the consequences of this document being used for a purpose other than that purpose for which it was commissioned. The assessments and judgements contained herein should not be relied upon as legal opinion.

The findings and opinions are relevant to the dates of the site work and should not be relied upon to represent conditions at substantially later dates. The opinions included herein are based on the information obtained from the published information, investigations undertaken at the site and from our experience. If additional information becomes available which might impact our conclusions we request the opportunity to review the information reassess the potential concerns and modify our opinion if warranted.

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Memberships

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